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STUDIES OF INTENSITY AND SPECTRAL COMPOSITION OF LUNAR GAMMA-RADIATION ON THE AUTOMATIC STATION LUNA - 10

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For the study of the intensity and spectral composition of γ-radiation of lunar rocks on the space station Luna-10, brought into a selenocentric orbit on 3 April 1966, a 32-channel scintillation gamma-spectrometer was installed. The absence on the Moon of atmosphere, absorbing γ-radiation, allows us to conduct its registration directly from the orbit of the satellite. The counting rate decrease then taking place is connected with the decrease of the solid angle, under which the surface of the Moon is seen.

Similar to what is observed on the Earth, γ-radiation of the lunar surface must be connected with the presence in lunar rocks of natural radioactive elements, thorium and uranium, with their products of decay and also of natural radioactive isotopes of potassium K^{40}.

As is well known, methods of determination of potassium, thorium and uranium are devised for terrestrial rocks with the help of a gamma-spectrometer. The experiment with a gamma-spectrometer on Luna-10 was therefore set up in such a fashion that attempts could be made to estimate by γ-radiation of the Moon the relative content of K, Th and U in rocks, constituting the lunar surface.

The content of radioactive elements K, Th and U is an important indicator of geological processes which could take place on the Moon. The question about the degree of physico-chemical differentiation of lunar matter [1] presents the greatest interest. At the present time, there are no data on the chemical composition of lunar rocks. It is unclear whether the Moon has a crust analogous to the terrestrial crust (basalt, granite) or whether its surface is constituted by rocks, close in their composition to the primary, nondifferentiated matter (stone meteorites), chondrites, ultrabasic rocks.

From the analysis of various types of terrestrial rocks, it

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* ISSLEDOVANIYA INTENSIVNOSTI I SPEKTRAL'NOGO SOSTAVA GAMMA-IZLUCHENIYA LUNY NA AVTOMATICHESKOY STANTSII LUNA-10

is clear that the highest content of radioactive elements is observed in rocks composing the lithosphere--granites and somewhat less in continental basalts. During the transition to matter of stone meteorites and ultrabasic rocks, the concentrations of radioactive elements decreased by 2 - 3 orders. On the basis of knowledge of the concentration of K, Th and U in rock, one may thereby estimate, in principle, its type and consequently its composition.

At the same time, in contrast to the Earth, there exists on the Moon γ-radiation, arising from the interaction of primary cosmic particles with lunar matter. With the low concentrations of K, Th and U, the intensity of this radiation may result to be higher than the level of γ-radiation from the products of decay, Th, U and K^{40} [2], impeding the determination of K, Th and U concentrations.

The scintillation gamma-spectrometer included a detector of γ-radiation, which is a NaJ(Tl) crystal, 30 x 40 mm dimensions, conjugated with an FEU-16 photomultiplicator and a pulse amplitude analyzer. The device permitted to measure the γ-radiation spectrum on the background of charged particles.

The device registered the γ-radiation spectra in two bands: from 0.3 to 3.1 Mev and from 0.15 to 1.5 Mev. The switching of the bands was accomplished by a special command feed on board the station.

Expounded below are the first preliminary results of processing of γ-spectra obtained on the orbit of the lunar satellite and also on the flight trajectory Earth-Moon.

Results of the Experiment — For the first month of the work on the automatic station Luna-10, six spectra of γ-radiation were then obtained in the energy range from 0.3 to 3.1 Mev. In addition, the intensity of γ-radiation in the same energy region was measured at about fifteen points. The measurements encompassed a rather wide area of the surface, including the regions of "continents" and "maria" of the visible as well as the far side side of the Moon.

One of the spectral measurements of γ-radiation of lunar rocks is plotted in Figure 1 (curve 1) after substracting the background engendered by the interaction of cosmic rays with the material of the automatic station. The intensity of γ-radiation corresponds to the height at which the station (700 km) was located during the time of measurement.

Analysis of the shape of the lunar γ-spectra showed that they differ substantially from the spectra of the terrestrial γ-radiation, the shape of which being mainly determined by the content of natural radioactive elements in the rock. For the Moon, γ-radiation, arising from the interaction of cosmic rays with the lunar matter and during the decay of cosmogenous radioisotopes, composes the basic part of γ-radiation.

During the collision of primary cosmic particles with the nuceli of the rocks, free nucleons are formed according to the (p, xpn)-type reaction, which interacting in their turn with other nuclei, form nucleon cascades. The residual nuclei can be in excited condition, the transition from which to the ground state is attended by the emission of γ-quanta, of which the energies depend for each isotope upon the scheme of its energetic levels, i. e., the radiation is characteristic

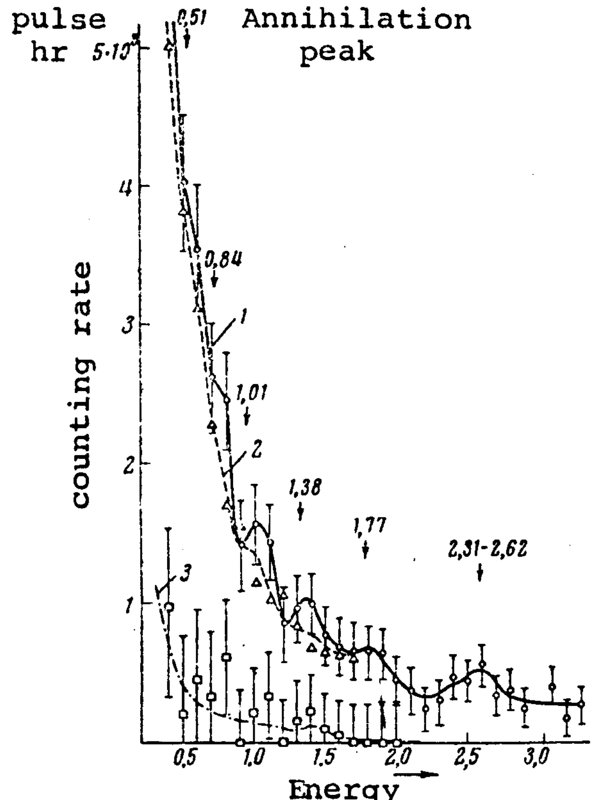

Fig.1

1-spectra of γ-radiation of lunar rock after the subtraction of the background; 2-spectra of γ-radiation, determined by processes of interaction of cosmic rays with lunar rocks (instant γ-radiation and decay of cosmogenous isotopes); 3-spectra of γ-radiation, connected with the decay of natural radioactive elements K, Th and U, contained in lunar rocks

Certain of the daughter nuclei, formed as a result of nuclear interactions, are radio active and may emit gamma-rays during decay. These are the co-called cosmogenous radioisotopes. On the lunar surface all the cosmogenous radioisotopes will be in radioactive equilibrium, i. e. long-lived as well as short-lived radioisotopes will be present among the emitters, of which the content will be proportional to their formation cross-section.

Calculations show that the basic contribution is provided by the decay of the following cosmogenous isotopes: O^{14}, O^{19}, F^{20}, Na^{22}, Na^{24}. These radioisotopes are formed with notable yield of main rock-forming elements O, Al, Mg, Si.

TABLE 1

Gamma-Ray Energies identified in the lunar γ- Spectrum

Energy Mev	Basic nuclear reactions leading to emission of γ-quanta of given energy
0,34	$Al^{27}(p, p'\gamma)Al^{27}$, $Si^{28}(p, 2p\gamma)Al^{27}$, $Fe^{56}(p, p', \gamma)Fe^{56}$
1,01	$Al^{27}(p, pn\gamma)Al^{26}$, $Si^{28}(p, 2pn\gamma)Al^{26}$
1,37	$Mg^{24}(p, p'\gamma)Mg^{24}$, $Al^{27}(p, pt\gamma)Mg^{24}$, $Si^{28}(p, p\alpha\gamma)Mg^{24}$
1,78	$Mg^{24}(p, p\alpha\gamma)Ne^{20}$, $Al^{27}(p, 2p\gamma)Mg^{26}$, $Si^{28}(p, p'\gamma)Si^{28}$
2,31 } 2,62 }	$O^{16}(p, 2pn\gamma)N^{14}$, $Mg^{24}(p, pn\gamma)Mg^{23}$, $Mg^{24}(p, 2p\gamma)Na^{23}$, $Al^{27}(p, ptn\gamma)Mg^{23}$

The energies of γ-rays, identified in the lunar γ-spectrum, are brought forth in Table I. Here too are indicated the basic nuclear reactions with probable similarly formed elements of lunar rock, as a result of which γ-rays of given energies are emitted.

Together with nuclear reactions, engendered by the emission of characteristic γ-quanta (instant γ-radiation and decay of cosmog nous radioisotopes), a certain contribution is provided by the decay processes of π°-mesons and the bremmstrahlung of electrons and protons. Spectra of the last two processes have a continuous character. As a consequence of this, the total spectrum of γ-radiation of the Moon becomes less prominent.

According to the preliminary data of the γ-spectra treatment, the general intensity of γ-radiation on the lunar surface exceeds by 1.5 - 2 times the intensity above the rocks of the terrestrial crust and it changes little with the transition from one region of the lunar surface to others. This result is apparently explained by the fact that the irradiation by cosmic particles is the basic source of γ-rays — a factor acting practically identically over the entire surface.

The estimate of the level of the natural activity and the determination of natural radioelement concentration can be made, if we subtract from the obtained lunar γ-spectrum the effect of γ-radiation determined by the interaction of cosmic rays with lunar rocks.

Admitting that the γ-radiation spectra, induced by cosmic rays in the material of the station and in the lunar rock, are identical in shape and only differ by the intensity, we obtained the γ-radiation spectrum of lunar rock, conditioned only by cosmic rays (Figure 1, curve 2).

Curve 3 (Figure 1) is the difference of the curves 1 and 2. This part of γ-radiation can be the result of the decay of natural radioactive elements.

As may be seen from the spectra plotted in Figure 1, approximately 90% of γ-radiation of the total intensity of lunar rocks is due to cosmic'rays and not more than 10% is ascribed to the decay of K, Th and U.

The gamma-spectrometer, intended for the study of lunar γ-radiation was preliminarily calibrated in terrestrial conditions on standard specimens with known compositions of K, Th and U and also on rock samples with a different content of these elements. On the basis of these data it was found possible to compute the γ-spectra which must be obtained during measurement on the orbit of the satellite for rocks with different contents of natural radioactive elements (with the absence of radiation due to cosmic rays). The average values of the concentrations of K, Th and U, utilized for the concentration of spectra, were borrowed from the work [3].

The comparison of γ-radiation from the decay of natural radioactive elements K, Th and U with the results of calibrations of the device on terrestrial rocks permits us to ascribe the concentrations of radioactive elements, similar to terrestrial rocks of the basic type (basalts with a content of radioactive elements) to lunar rocks. The obtained data allow us to exclude for those regions of the lunar surface where measurements are brought forth, the existence of rocks with the same content of radioactive elements K, Th and U as in acid terrestrial rocks (granite) and so much the more of rocks with ore segregations of these elements. At the same time, the exclusion of the possibility of existence for these regions on the lunar surface of ultrabasic (meteorites) matter does not seem probable at present.

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